Fire Signatures Provided by Laser Technology Spot Smoke Detectors

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Introduction

Systems used for very early warning of smoke and fire must be capable of sensing extremely low smoke levels, with obscuration values of 0.03% per foot or less. These systems are primarily used in applications involving high value electrical equipment that are susceptible to short circuits failures giving slow, smoldering fires. Because of the high sensitivity, such early warning systems are susceptible to false alarms from non-smoke airborne particles, such as dust, lint, human hair, and even small insects. Early warning technology today (aspiration) commonly uses a fan to pull the smoke through a filter, separating the small smoke particles from the larger non-smoke particles, and thereby allowing the systems to be set to very high sensitivity without false alarms.

The method of detection described in this abstract uses a focused laser light source to scatter light in the presence of smoke. It will be shown that this type of light source gives different signatures for smoke than for dust and other particles. In addition, further differentiation between smoke and non-smoke particles can be obtained by using multiple sensors in one room, and observing differences in their analog light scattering signals. Using these methods, an early warning fire detection system can be constructed which will discriminate between smoke and non-smoke particles, yet does not require filters or moving parts, and therefore offers a lower cost alternative for early warning applications.

Description of the Detector Technology

The detector light source is a laser diode, coupled to a lens such that it creates a narrow but very intense light beam. The light beam travels across the detector and is absorbed by a light trap on the opposite side. At an angle to the light beam is a photo sensitive receiver that normally (clear air) is not struck by the laser light photons and gives no signal. When smoke particles enter the detector, the light strikes the particles and is scattered in all directions. Some of this scattered light reaches the photo receiver, which provides the system with the basic indication of smoke. The design can be made more sensitive, without increasing the sensitivity to electrical noise, by use of a mirror to reflect additional scattered light into the photo receiver, acting as an optical amplifier.

Since the light beam is tightly focused, it touches no detector surfaces, and spurious light will not be reflected into the photo receiver. This eliminates most false signals caused by the accumulation of dust and other particles on the detector surfaces, changing the surface color from flat black to gray.

Smoke and Non-Smoke Signatures

If the focused laser light beam is made with a very small volumetric region in which light scattering is measured, different signatures can be detected for smoke compared to dust. In comparison to smoke particles, dust particles are large and relatively sparse. In reasonably clean environments, a dust particle large enough to cause a significant signal at the photo receiver will only enter the light-scattering region occasionally. Extensive tests have shown that such particles occur with an order of magnitude of once per hour. Since the airborne dust particles are constantly in motion, they drift out of the light scattering volumetric region in a few seconds. Thus, the signature of airborne dust has a transient nature. In comparison, the signature of true smoke, while it has oscillations in amplitude, has a much more continuous and persistent nature. Signal processing algorithms can be developed which will differentiate between these two phenomena.

Very large airborne particles, including fibers such as lint and human hair, provide a separate problem, in that they can land on a surface while protruding into the light beam volume. Although much less common than dust particles, long term tests have shown that fiber contamination is not an insignificant problem with smoke detectors. Although detector screens intuitively seem to provide protection from fiber entry, tests have shown that fibers have a surprising ability to breach them. Apparently, once one end of the fiber touches a screen hole opening, the fiber can thread completely through the opening.

When a fiber lands in the light-scattering volumetric region, its typical signature is that of a step function. Since the laser light source is so intense in the region, the step amplitude is usually sufficient to alarm the detector. This fiber signature is different from smoke, which has an oscillating signal with a relatively slow rise time from the clear air reading to the alarm threshold.

Discrimination of fibers from smoke can also be achieved by use of two or more detectors in the protected space, along with analog signal processing in a central control panel. On detection of a signal that looks suspiciously like a fiber, the processing algorithms can look at the analog signal from a second detector before making a decision. If no signal is received over a period of time, even a very low signal, existence of a fiber in the first detector is confirmed.

Test Results

Stability tests (rejection of non-smoke signals) have been performed using a large number of laser spot detectors located in an industrial facility. The detectors were connected to a control panel with software algorithms based on the signature information described above. In over 1 million detector-hours of testing, these algorithms rejected all dust and fiber false signals.

Smoldering fire tests were performed at a major telecommunications switching office, using the Notifier VIEW system, an implementation of the signal processing described above. The VIEW system was installed along with a very early warning aspiration system, commonly used today. In a series of 7 tests, using different burn rates, fire location, fire fuel, and room air flow rates, the VIEW system performance was equal or better than the aspiration system.